

Markscheme

May 2016

Chemistry

Higher level

Paper 3

27 pages

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Subject Details: Chemistry HL Paper 3 Markscheme

Mark Allocation

Candidates are required to answer **ALL** questions in Section A [**15 marks**] and all questions from **ONE** option in Section B [**30 marks**].
Maximum total = [**45 marks**].

1. Each row in the “Question” column relates to the smallest subpart of the question.
2. The maximum mark for each question subpart is indicated in the “Total” column.
3. Each marking point in the “Answers” column is shown by means of a tick (✓) at the end of the marking point.
4. A question subpart may have more marking points than the total allows. This will be indicated by “**max**” written after the mark in the “Total” column. The related rubric, if necessary, will be outlined in the “Notes” column.
5. An alternative word is indicated in the “Answers” column by a slash (/). Either word can be accepted.
6. An alternative answer is indicated in the “Answers” column by “**OR**”. Either answer can be accepted.
7. An alternative markscheme is indicated in the “Answers” column under heading **ALTERNATIVE 1** etc. Either alternative can be accepted.
8. Words inside chevrons « » in the “Answers” column are not necessary to gain the mark.
9. Words that are underlined are essential for the mark.
10. The order of marking points does not have to be as in the “Answers” column, unless stated otherwise in the “Notes” column.
11. If the candidate’s answer has the same “meaning” or can be clearly interpreted as being of equivalent significance, detail and validity as that in the “Answers” column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by **OWTTE** (or words to that effect) in the “Notes” column.
12. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

13. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script. “ECF acceptable” will be displayed in the “Notes” column.
14. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the “Notes” column.
15. If a question specifically asks for the name of a substance, do not award a mark for a correct formula unless directed otherwise in the “Notes” column. Similarly, if the formula is specifically asked for, do not award a mark for a correct name unless directed otherwise in the “Notes” column.
16. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the “Notes” column.
17. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the “Notes” column.

Section A

Question			Answers	Notes	Total
1.	a		ozone: yes because it absorbs IR ✓ oxygen: no because it does not absorb IR ✓		2
	b	i	Any value in the range: 1300–1500 ✓	(It is in fact 1403 using the same measurement technique as that used to get the data in the table).	1
	b	ii	CCl ₄ is symmetrical/dipoles of C–Cl bonds cancel out OR fluorine/F more electronegative ⟨than chlorine/Cl⟩ OR C–F bond more polar ⟨than C–Cl bond⟩ ✓ ⟨vector⟩ sum of bond polarities in CCl ₃ F non-zero/greater than that in CCl ₄ OR dipoles of ⟨three⟩ C–Cl bonds do not cancel the dipole of C–F bond ✓	Accept suitable diagrams.	2
	b	iii	GWP increases as IR intensity increases ✓	Accept converse statements.	1
	b	iv	no relationship and CO ₂ and CCl ₄ /CF ₄ are non-polar/have zero dipole moment (but) have very different integrated IR intensities ✓	Accept a plot or sketch with a comment that “changes along x-axis produce random changes along y-axis”.	1
	b	v	⟨data from table such as integrated IR and GWP indicate that they⟩ contribute significantly to global warming ✓ persistent in atmosphere ✓ cause ozone depletion ✓ development ⟨of refrigerants⟩ inadvertently caused problems ✓		2 max

(continued)

Question			Answers	Notes	Total
2.	a		<p>carefully dissolve pellets/handle concentrated solution as corrosive/ reaction exothermic ✓</p> <p>pour/add <the concentrated solution> to a <1.00 dm³> <u>volumetric flask</u> ✓</p> <p>volumetric flask has low uncertainty in measurement ✓</p> <p>fill up to line/mark/1 dm³ with <dionized/distilled> water when at room temperature OR fill up to line/mark/1 dm³ with <dionized/distilled> water mixing the solution <homogeneously> ✓</p>		2 max
	b	i	blue to green/yellow ✓		1
	b	ii	<p>equivalence point has been exceeded/too much acid has been added ✓</p> <p>calculated concentration increased OR uncertainty increased ✓</p>		2
	c		<p>temperature of NaOH solution changed during experiment OR intensity of colour difficult to detect ✓</p>	<i>Accept any valid hypothesis.</i>	1

(continued)

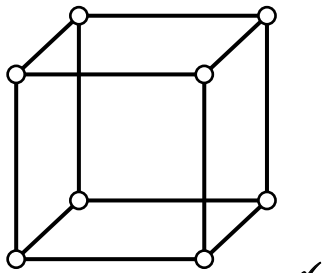
Section B

Option A — Materials

Question			Answers	Notes	Total
3.	a		$\text{Fe}_2\text{O}_3(\text{s}) + 3\text{CO}(\text{g}) \rightarrow 2\text{Fe}(\text{l}) + 3\text{CO}_2(\text{g})$ ✓		1
	b		<p>Fe_2O_3: paramagnetic and unpaired electrons present so magnetic moments do not cancel out ✓</p> <p>Al_2O_3: diamagnetic and electrons are all paired so magnetic moments cancel out ✓</p>	Award [1] for “ Fe_2O_3 paramagnetic and Al_2O_3 diamagnetic”.	2
	c		<p>$n(\text{e}) = \frac{2.00 \times 10^6}{96500} = 20.7 \text{ } \langle \text{mol} \rangle$</p> <p>OR</p> <p>$n(\text{Al}) = \frac{1}{3} n(\text{e}) = 6.91 \text{ } \langle \text{mol} \rangle$ ✓</p> <p>$m(\text{Al}) = 6.91 \times 26.98 = 186 \text{ } \langle \text{g} \rangle$ ✓</p>	Award [2] for correct final answer.	2
	d	i	collisions between electrons and positive ions/metal atoms/metal lattice ✓		1
	d	ii	<p>metal II is a superconductor ✓</p> <p>passing electrons $\langle \text{slightly} \rangle$ deform lattice/displace positive ions and couple/form Cooper pairs/condense with other electrons ✓</p> <p>energy propagates along the lattice in wave-like manner/as phonons ✓</p> <p>Cooper pair/electron condensate moves through lattice freely OR phonons are $\langle \text{perfectly} \rangle$ elastic/cause no energy loss ✓</p>		3 max

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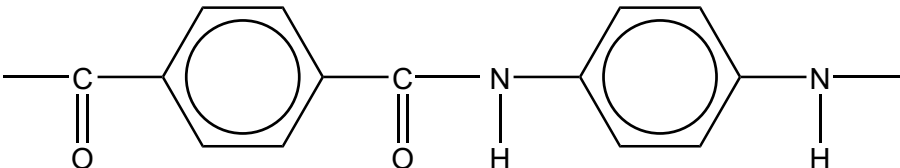
(Question 3 continued)

Question			Answers	Notes	Total
	e	i	 ✓ <coordination number => 6 ✓		2
	e	ii	<Bragg equation, $n = 1$ > $d = \frac{8.80 \times 10^{-11}}{2 \times \sin(13.0)} \Rightarrow 1.96 \times 10^{-10} \text{ m} \text{ ✓}$		1

4.	a		possible toxicity <of small (airborne) particles> OR unknown health effects OR immune system/allergy concerns OR uncertain impact on environment ✓		1
	b		EITHER pores/cavities/channels/holes <in zeolites> have specific shape/size ✓ only reactants that fit inside go through/are activated/can react ✓ OR zeolites have cage-like structure/are porous ✓ only reactants with appropriate size/geometry fit inside and go through/are activated/can react ✓		2

(continued)

(Question 4 continued)

Question			Answers	Notes	Total
	c		<p><i>Catalyst:</i> iron/Fe OR iron<0> <penta> carbonyl/Fe(CO)₅ ✓</p> <p><i>Conditions:</i> high temperature/ 900–1600 °C and high pressure/10–100 atm ✓</p>		2
5.			<p>ceramics have a giant ionic/covalent structure ✓</p> <p>metals contain lattice of positive metal ions in sea of delocalized electrons ✓</p>		2
6.	a		<p><CN group> makes molecule polar ✓</p> <p>alignment/orientation of molecules can be controlled by electric field ✓</p>		2
	b	i	 <p>/</p> <p>—COC₆H₄CONHC₆H₄NH— ✓</p>	Continuation bonds are necessary for the mark.	1
	b	ii	H bonds form between chains <from NH of one chain to CO of the next> ✓		1

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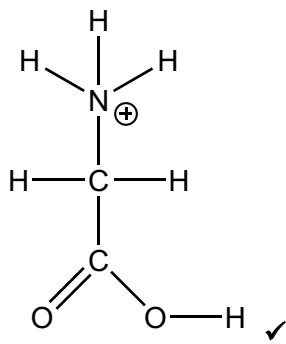
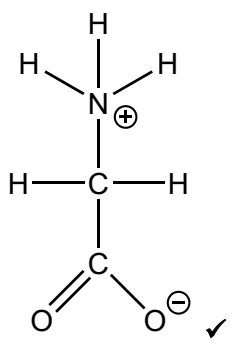
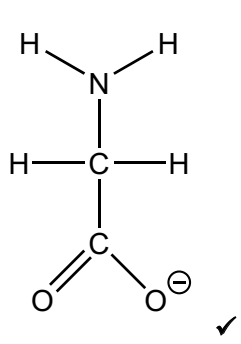
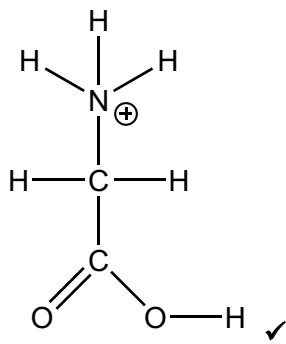
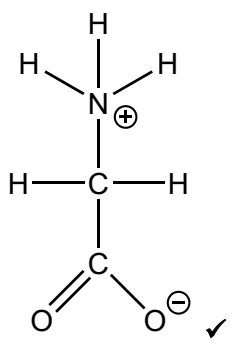
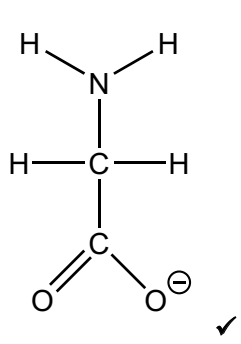
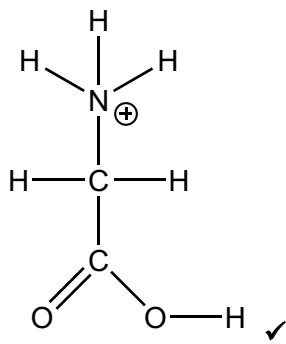
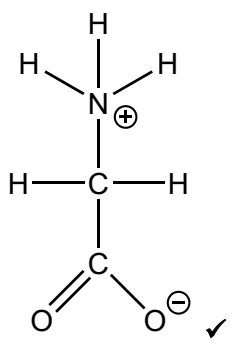
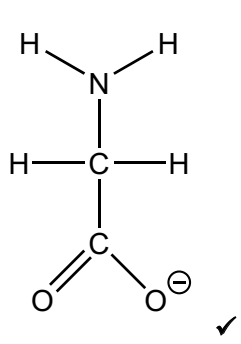
Question			Answers	Notes	Total
7.	a		plasticizer molecules fit between chains OR increase space between chains ✓ weaken intermolecular forces ✓		2
	b		does not degrade «so large volume in landfill» ✓ concerns about resource waste ✓ incineration produces dioxins/toxic compounds ✓		1 max

8.	a		$\text{Fe}^{3+} + \text{O}_2^- \rightarrow \text{Fe}^{2+} + \text{O}_2$ ✓ $\text{Fe}^{2+} + \text{H}_2\text{O}_2 \rightarrow \text{Fe}^{3+} + \cdot\text{OH} + \text{OH}^-$ ✓	Award [1] for the net equation $\text{H}_2\text{O}_2 + \text{O}_2^- \rightarrow \text{HO}\cdot + \text{OH}^- + \text{O}_2$ Accept the OH radical without the radical sign.	2
	b		$K_{\text{sp}} = [\text{Zn}^{2+}][\text{OH}^-]^2 = 3 \times 10^{-17}$ $[\text{OH}^-] = 2[\text{Zn}^{2+}]$ ✓ $4[\text{Zn}^{2+}]^3 = 3 \times 10^{-17}$ $\llbracket [\text{Zn}^{2+}] = \sqrt[3]{7.5 \times 10^{-18}} \Rightarrow 2 \times 10^{-6} \llbracket \text{mol dm}^{-3} \rrbracket$ ✓	Award [2] for correct final answer. Award [1] for 5.5×10^{-9} or $6 \times 10^{-9} \llbracket \text{mol dm}^{-3} \rrbracket$.	2

(continued)

Option B — Biochemistry

Question			Answers	Notes	Total
9.	a	i	alkenyl ✓	<i>Accept alkene.</i>	1
	a	ii	fused ring structure OR three 6-membered rings and a 5-membered ring OR four-ring ⟨steroidal⟩ backbone ✓		1
	b		medical uses of steroids ⟨under physician supervision⟩ OR detection of banned substances has/can be improved OR understanding the health hazards is improved ✓	<i>Accept any medicalized specific use.</i>	1

10.	a		<table><tr><th>pH 1.0</th><th>pH 6.0</th><th>pH 11.0</th></tr><tr><td></td><td></td><td></td></tr></table>	pH 1.0	pH 6.0	pH 11.0				<i>Charges must be shown in structure for mark. Penalize repeated mistakes once.</i>	3
pH 1.0	pH 6.0	pH 11.0									
											

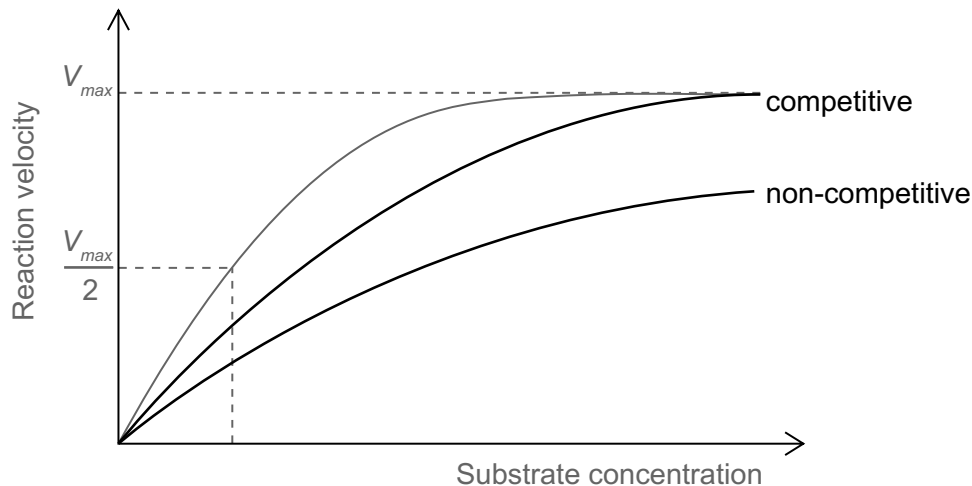
(continued)

(Question 10 continued)

Question			Answers	Notes	Total
	b	i		<p>Award [2] for correct order.</p> <p>Award [1] for Leu in center if order is incorrect.</p>	2
	b	ii	6 ✓	Accept correct concepts expressed in other ways.	1
	c	i		<p>Accept un-ionized or zwitterionic forms.</p> <p>Accept any other correct representation which clearly indicates 3-dimensional structure at chiral center.</p> <p>Accept Fisher projections with the chiral carbon atom represented by crossing lines or shown as C.</p>	1
	c	ii	L ✓		1

11.	a		$\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}$ ✓		1
	b		$n(\text{C}_6\text{H}_{12}\text{O}_6) \left(= \frac{15.0}{180.18} \right) = 0.0833 \text{ mol} \checkmark$ $\text{energy} = 0.0833 \times 2803 \Rightarrow 233 \text{ kJ} \checkmark$	Award [2] for correct final answer.	2

(continued)

Question			Answers	Notes	Total
12.	a		 <p>graph showing competitive inhibitor eventually reaching V_{\max} ✓</p> <p>graph showing non competitive inhibitor not reaching V_{\max} ✓</p>	<p><i>Curves must be labeled and should not cross given curve.</i></p> <p><i>Penalize one mark if curves cross.</i></p>	2
	b		$\log \frac{(3.70 \times 10^{-3})}{(2.60 \times 10^{-3})} = 0.153$ ✓ $\langle 4.76 + 0.153 \Rightarrow 4.91$ ✓	<p><i>Accept 4.9.</i></p> <p><i>Award [2] for correct final answer.</i></p> <p><i>Accept other methods of calculation.</i></p>	2
13.	a		<p>A and D have few polar/hydroxyl/OH groups \langlebut C has many of those\rangle</p> <p>OR</p> <p>A and D have hydrocarbon/six-membered carbon rings \langlebut C has heterocyclic/five-membered ring\rangle ✓</p> <p>OR</p> <p>A and D have long hydrocarbon chains ✓</p>	<p><i>Accept other valid similarities and differences.</i></p>	1
	b		0.50 and chlorophyll b ✓		1

(continued)

Question			Answers	Notes	Total
14.	a		<p>low CO₂ level causes more oxygen to be bound to the heme ✓</p> <p>high pH causes more oxygen to be bound to the heme ✓</p> <p>low temperature more oxygen to be bound to the heme ✓</p> <p>high organic phosphates/2,3-BPG/DPG which can bind to heme and increases affinity for oxygen ✓</p> <p>CO decreases saturation/binds to active site/competitive inhibitor ✓</p>	<i>Accept reverse statements for mark.</i>	3 max
	b		<p>contains two gamma units ⟨instead of the two beta units found in adults⟩ OR differs slightly in amino acid sequence ⟨from the two beta units found in adults⟩ ✓</p> <p>less sensitive to inhibitors/2,3-BPG/DPG ✓</p> <p>receives O₂ from ⟨partly deoxygenated⟩ blood so must work at low pO₂ ✓</p>	<i>Accept reverse statements for mark.</i>	2 max

Option C — Energy

Question			Answers	Notes	Total
15.	a	i	2,2-dimethylbutane OR 2,3-dimethylbutane OR 3-methylpentane OR 2-methylpentane OR cyclohexane OR methylcyclopentane OR benzene ✓	<i>Accept names or formulas.</i>	1
	a	ii	increased branching OR tertiary free radicals are more stable OR higher octane rating ✓		1
	b	i	$\left\langle \frac{5470}{114.26} \right\rangle = \left\langle 47.9 \text{ kJ g}^{-1} \right\rangle$ ✓		1

(continued)

(Question 15 continued)

Question			Answers	Notes	Total
	b	ii	<p><i>Advantage:</i> ethanol does not produce particulates OR ethanol has high octane rating OR ethanol is renewable ✓</p> <p><i>Disadvantage:</i> ⟨but⟩ reduces efficiency ⟨as ethanol has lower specific energy⟩ OR ethanol is more volatile ⟨than octane or its isomers⟩ OR land that could be used for food production used to produce crops for ethanol ✓</p>		2
	c		<p>$2\text{C(s)} + 2\text{H}_2\text{O(g)} \rightarrow \text{CH}_4\text{(g)} + \text{CO}_2\text{(g)}$ OR $3\text{C(s)} + 2\text{H}_2\text{O(g)} \rightarrow \text{CH}_4\text{(g)} + 2\text{CO(g)} \checkmark$</p>		1

16.	a		<p><i>Reagent:</i> methanol/CH_3OH OR ethanol/$\text{C}_2\text{H}_5\text{OH}$ ✓</p> <p><i>Catalyst:</i> strong acid OR strong base ✓</p>	<p><i>Accept any strong acid such as sulfuric acid/H_2SO_4.</i></p> <p><i>Accept any strong base such as sodium hydroxide/NaOH.</i></p>	2
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(continued)

(Question 16 continued)

Question			Answers	Notes	Total
	b		different solutions can be compared OR best ideas can be shared to arrive at global/local solutions OR acceleration of research <discoveries become available to everyone> OR improved confidence <statistical data can be compared/combined> OR money/effort/time is not wasted duplicating work others have already done ✓		1

17.	a		${}_{90}^{232}\text{Th} + {}_6^{12}\text{C} \rightarrow {}_{96}^{240}\text{Cm} + 4{}_0^1\text{n}$ ✓	Accept ${}^{232}\text{Th} + {}^{12}\text{C} \rightarrow {}^{240}\text{Cm} + 4\text{n}$.	1
	b	i	$\langle \lambda = \frac{\ln 2}{7.038 \times 10^8} \Rightarrow 9.849 \times 10^{-10} \text{ <years>}^{-1} \rangle$ ✓		1
	b	ii	<3 half-lives, so> $2.11 \times 10^9 \text{ <years>}$ ✓		1
	b	iii	produces free radicals ✓ <initiates chain reactions that can> damage DNA OR <initiates chain reactions that can> damage cells OR <DNA damage causes> mutations/cancer/apoptosis/cell death/weakening of immune system ✓	Accept other negative biochemical and/or medical effects.	2
	c	i	mass of helium-4 nucleus = $4 \times 1.66 \times 10^{-27} = 6.64 \times 10^{-27} \text{ <kg>}$ OR mass of nucleons = $2 \times 1.672622 \times 10^{-27} + 2 \times 1.674927 \times 10^{-27} = 6.695098 \times 10^{-27} \text{ <kg>}$ ✓ <mass defect = $6.695098 \times 10^{-27} - 6.64 \times 10^{-27} \Rightarrow 5.51 \times 10^{-29} / 0.06 \times 10^{-27} / 6 \times 10^{-29} \text{ <kg>}$ ✓	Award [2] for correct final answer.	2

(continued)

(Question 17 continued)

Question			Answers	Notes	Total
	c	ii	$\text{binding energy} = \frac{\Delta m \times c^2}{\text{nucleons}} = \frac{6 \times 10^{-29} \times (3.00 \times 10^8)^2}{4}$ $= 1 \times 10^{-12} \text{ kJ nucleon}^{-1} \checkmark$	<i>The use of 5.51×10^{-29} and 5.00×10^{-29} will respectively give 1.23×10^{-12} and 1.13×10^{-12}.</i>	1
18.			$\text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{HCO}_3^-(\text{aq})$ OR $\text{CO}_2(\text{g}) \rightleftharpoons \text{CO}_2(\text{aq})$ and $\text{CO}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{HCO}_3^-(\text{aq}) \checkmark$ increasing $[\text{CO}_2]$ shifts equilibrium to right/increases $[\text{H}^+] \checkmark$ pH decreases \checkmark	<i>Accept $\text{H}_2\text{CO}_3(\text{aq})$ instead of $\text{CO}_2(\text{aq})$. Do not award M1 if states of CO_2 not shown or incorrect.</i>	3
19.			bond length changes/⟨asymmetric⟩ stretching OR bond angle changes/bends \checkmark polarity/dipole moment changes \checkmark	<i>Accept appropriate diagram.</i>	2
20.	a		<i>Negative electrode (anode):</i> $\text{CH}_3\text{OH}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{CO}_2(\text{g}) + 6\text{H}^+(\text{aq}) + 6\text{e}^- \checkmark$ <i>Positive electrode (cathode):</i> $\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}(\text{l}) \checkmark$	<i>Accept $\frac{3}{2} \text{O}_2(\text{g}) + 6\text{H}^+(\text{aq}) + 6\text{e}^- \rightarrow 3\text{H}_2\text{O}(\text{l})$.</i>	2

(continued)

(Question 20 continued)

Question			Answers	Notes	Total
	b		<p><i>Advantage:</i> produces continuous supply of electricity <on addition of more raw materials> OR does not need to be recharged OR less hazardous if broken or exposed to the environment OR weighs much less than lead-acid battery ✓</p> <p><i>Disadvantage:</i> more expensive OR needs constant supply of fuel OR methanol/ethanol fuel cells difficult to use in cold weather OR methanol/ethanol fuel cells produce carbon dioxide OR storage/transport of gases/hydrogen a problem in hydrogen fuel cell OR potentially explosive/hydrogen is flammable ✓</p>		2

21.	a		<p><i>n-type:</i> <small amount of> As/Sb/group 15 element added and <extra> electrons ✓</p> <p><i>p-type:</i> <small amount of> Ga/In/group 13 element added and <extra electron> holes ✓</p>	<p>Award [1 max] if only doping elements or only charge carriers are given. Accept “group 5” for “group 15”.</p> <p>Accept “group 3” for “group 13”.</p>	2
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(continued)

(Question 21 continued)

Question			Answers	Notes	Total
	b		large surface area <increases chance photon will be absorbed> ✓ <dye allows> absorption of a wide range of wavelengths OR dye converts most/all absorbed photons into electrons ✓		2

Option D — Medicinal chemistry

Question			Answers	Notes	Total
22.	a		beta-lactam ring is strained OR ring breaks easily ✓ bonds covalently/interferes with the enzyme/transpeptidase that synthesizes the bacterium cell wall ✓ inhibits cross linking in bacteria cell walls OR bacteria burst ⚡from high osmotic pressure⚡ OR cell cannot reproduce ✓		3
	b		bacteria can become resistant pollute the environment ⚡overuse in livestock⚡ loss of useful bacteria weakening of the immune system/natural body resistance to diseases ✓	Any two for [1 max] .	1

23.	a		<table><tr><th>Reagent</th><th>By-product</th></tr><tr><td>(CH₃CO)₂O</td><td>CH₃COOH</td></tr><tr><td>OR</td><td>OR</td></tr><tr><td>CH₃COCl</td><td>HCl</td></tr><tr><td>OR</td><td>OR</td></tr><tr><td>CH₃COOH ✓</td><td>H₂O ✓</td></tr></table>	Reagent	By-product	(CH ₃ CO) ₂ O	CH ₃ COOH	OR	OR	CH ₃ COCl	HCl	OR	OR	CH ₃ COOH ✓	H ₂ O ✓	Award M2 if only the by-product correspond to the reagent.	2
Reagent	By-product																
(CH ₃ CO) ₂ O	CH ₃ COOH																
OR	OR																
CH ₃ COCl	HCl																
OR	OR																
CH ₃ COOH ✓	H ₂ O ✓																

(continued)

(Question 23 continued)

Question			Answers	Notes	Total
	b		morphine has two hydroxyl groups and diamorphine/heroin has two ester groups ✓ morphine is more polar than diamorphine/heroin ✓ morphine does not cross the blood-brain barrier as well as diamorphine/heroin ✓ morphine is better soluble in the blood plasma while diamorphine/heroin is better soluble in lipids ✓	Accept converse argument. Accept “alcohol” for “hydroxyl”.	3 max
	c		spectrum A is diamorphine because it has a strong peak at 1700–1750 cm ⁻¹ OR spectrum A is diamorphine because it has a C=O/carbonyl (group)/ester ✓ spectrum B is morphine because it has a strong broad peak at 3200–3600 cm ⁻¹ OR spectrum B is morphine because it has a –OH/hydroxyl (group) ✓	Accept “alcohol” for “hydroxyl”.	2
24.	a		$\text{Mg(OH)}_2(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow 2\text{H}_2\text{O}(\text{l}) + \text{MgCl}_2(\text{aq})$ OR $\text{Mg(OH)}_2(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$ ✓		1

(continued)

(Question 24 continued)

Question			Answers	Notes	Total
	b		<p>both compounds relieve symptoms of acid reflux/ heartburn OR both compounds relieve symptoms of indigestion ✓</p> <p>omeprazole stops the production of acid and magnesium hydroxide neutralizes the acid that is present ✓</p> <p>omeprazole takes longer <than magnesium hydroxide> to provide relief OR magnesium hydroxide provides faster relief <than omeprazole> ✓</p> <p>omeprazole can prevent long term damage from overproduction of acid and magnesium hydroxide does not prevent acid damage ✓</p> <p>magnesium hydroxide affects ionic balance in the body/produces <many> side effects and omeprazole does not affect ionic balance/has few<er> side effects ✓</p>		3 max

25.	a		Example	Treatment	<p>Award 1 mark for example and corresponding treatment. Award [1 max] for the two types of waste.</p>	2
			gowns/gloves/syringes/ needles/cotton swabs	and storage < in shielded container > until isotope has decayed, then dispose as normal/non-radioactive waste ✓		
			radioactive sources/ equipment for external radiotherapy	and store <u>underground</u> /bury ✓		

(continued)

(Question 25 continued)

Question			Answers	Notes	Total
	b		${}_{84}^{216}\text{Po} \rightarrow {}_2^4\text{He} + {}_{82}^{212}\text{Pb}$ correct reactant ✓ correct alpha particle ✓	Atomic numbers not required for mark. Accept α symbol.	2
	c		Advantage: selectively kills cancer cells ✓ Cancer treatment: melanoma OR leukemia OR rectal OR breast OR ovarian OR prostate OR pancreatic OR cancers that spread around the body/produce metastases ✓	Accept skin cancer.	2

(continued)

(Question 25 continued)

Question			Answers	Notes	Total
	d		<p>EITHER</p> $\lambda = \frac{\ln 2}{6.01} \approx 0.115 \text{ h}^{-1} \checkmark$ $\langle \text{remaining mass} = 5.80 \times 10^{-9} \times e^{-0.115 \times 24.04} \Rightarrow 3.63 \times 10^{-10} \text{ g} \rangle \checkmark$ <p>OR</p> $\frac{24.04}{6.01} = 4 \text{ half-lives} \checkmark$ $\langle \frac{5.80 \times 10^{-9}}{2^4} \Rightarrow 3.63 \times 10^{-10} \text{ g} \rangle \checkmark$	Award [2] for correct final answer.	2
	e		<p>risk vs benefit (patient and environment)</p> <p>OR</p> <p>security</p> <p>OR</p> <p>cultural resistance/superstition/lack of education ✓</p>		1

26.	a		ether ✓		1
	b		<p>Number of signals: 3 (signals) ✓</p> <p>Relative integration: 6:4:1 ✓</p>	Accept any correct ratio order.	2
	c	i	polarimeter ✓	Accept other alternative techniques such as "GC/HLPC/chromatography using a chiral column".	1

(continued)

(Question 26 continued)

	c	ii	polarized light passed through sample ✓ analyser/second polarizer detects whether plane of polarization rotated OR each enantiomer will rotate plane (of plane–)polarized light differently ✓	<i>Accept explanation related to other alternative techniques such as GC/HPLC/chromatography using a chiral column.</i>	2
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